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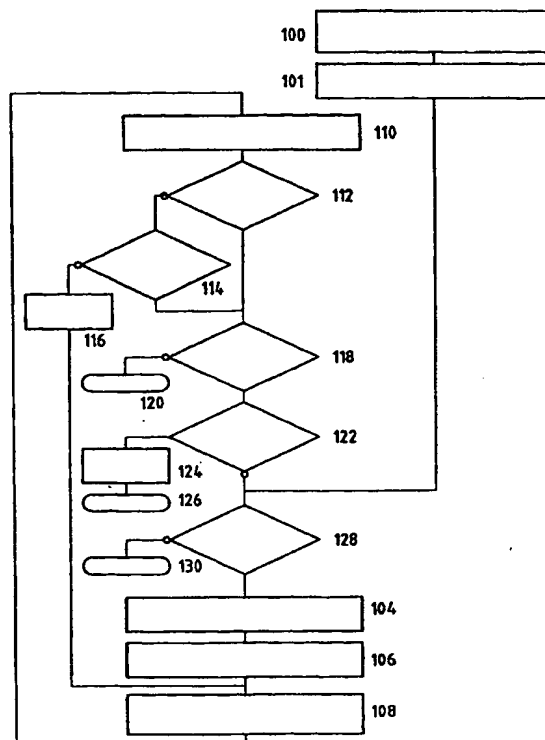
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(54) Title: ROUTING METHOD FOR WIRELESS AND DISTRIBUTED SYSTEMS AND DEVICES ADAPTED ACCORDINGLY

(57) Abstract

Method for routing packets (2) within a wireless telecommunication network (3), wherein the packets are transmitted from one source station (5) to at least one sink station (6) through a plurality of mobile relay stations ( $N_{i-1}$ ,  $N_i$ ,  $N_{i+1}$ ). The packets can be directly transmitted (108-110) through a wireless link (7) between neighbour mobile relay stations ( $N$ ,  $N_{i-1}$ ,  $N_i$ ,  $N_{i+1}$ ). The routing of packets in the mobile relay stations ( $N_i$ ) is based on information autonomously monitored by this mobile relay station ( $N_i$ ) about its neighbour mobile relay stations ( $N$ ,  $N_{i-1}$ ,  $N_{i+1}$ ). Each packet is routed in said mobile relay station ( $N_i$ ) to one, or more, next station(s) ( $N_{i+1}$ ) chosen from among the set of all of its neighbour mobile relay stations ( $N$ ,  $N_{i-1}$ ,  $N_{i+1}$ ). Each packet (2) contains a header indicating the source station (5) which emitted the packet, at least one sink station (6) to which the packet is destined, and the neighbour mobile relay station ( $N_{i+1}$ ) to which said packet will be transmitted in the next hop. The indication of the next neighbour mobile relay station ( $N_{i+1}$ ) is replaced in each mobile relay station ( $N_i$ ). The choice (104) of the next station ( $N_{i+1}$ ) made from among the mobile relay stations ( $N_i$ ) depends on the distance between the next mobile relay station ( $N_{i+1}$ ) and the sink station (6). The position of the mobile relay stations (4, 5, 6,  $N$ ,  $N_{i-1}$ ,  $N_i$ ,  $N_{i+1}$ ) may be determined by a positioning system, e.g., a GPS, in the mobile relay stations and communicated to all neighbour mobile relay stations.



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## **Routing Method for Wireless and Distributed Systems and Devices Adapted Accordingly**

The present invention relates to a routing method for wireless and distributed systems and to devices adapted accordingly. Specifically, the present invention relates to a method for routing packets within a wireless telecommunication network, said packets being transmitted from one source station in said network to at least one sink station through one or a plurality of relay stations, and to adapted mobile stations which can be used in such a wireless telecommunication network.

A method for routing data packets within a wireless network is described in the patent application WO 97/32419. The method described therein is a random multiple path tabular routing method, wherein a plurality of individual nodes are programmed to serve as repeater nodes, said repeater nodes forming multiple programmed communication paths between a central node and some selected individual nodes. However, the method described in WO 97/32419 is not suitable for a wireless telecommunication network with mobile stations because it is deterministic to the extent that routing tables are used to program the multiple communication paths based on connectivity information obtained during the network initialisation process.

The patent application WO 97/24840 describes a method for automatically initialising a wireless, packet-hopping network, such as a building system control network, whereby each node in the network determines its entire connectivity, by transmitting initialisation packets requesting a response from the nodes receiving these packets, and then routes this connectivity information to a central computer. The exchange of packets for requesting and transmitting connectivity information by all nodes in the network represents a network overhead which can be acceptable as a one-time initialisation process in a fixed network but which would be disadvantageous in a network with mobile stations where this process would have to be repeated frequently. Furthermore, storing routing information in a central computer means that the nodes in the network need to request that information from this central computer when they route a packet to another node in the network.

The patent application DE 3337648 A1 describes a radio network with a plurality of mobile stations, each of which can function as a relay station between pairs of communicating mobile stations. In the radio network described in DE 3337648 A1, data about the state of the network, the possible routes to  
5 all other mobile stations, and the availability and operational states of the individual connections is determined and maintained by each mobile station and, on request, passed on to requesting other mobile stations. Thus, DE 3337648 A1 describes a radio network, in which mobile stations can provide routes between communicating stations without the need for centralized routing  
10 information, but by periodically requesting routing information from other mobile stations and by storing and maintaining this routing information locally. Consequently, in the radio network described in DE 3337648 A1, network capacity is used by all the mobile stations in the network for requesting and transmitting routing information from and to each other.

15 It is an object of this invention to propose a new and improved routing method for wireless telecommunication networks, and adapted mobile stations which can be used in such wireless telecommunication networks.

According to the present invention, these objects are achieved particularly through the features of the characterising part of the independent  
20 claims. In addition, further advantageous embodiments follow from the dependent claims and the description.

According to the proposed method for routing packets, for example data or speech packets, whereby packets are transmitted in a wireless telecommunication network from one source station to at least one sink station  
25 through one or a plurality of relay stations, whereby at least one of said relay stations is a mobile station, for example a mobile phone station, and whereby at least two of said stations are neighbour stations, wherein packets can be directly transmitted through a wireless connection between each pair of neighbour stations, these objects are particularly achieved in that the routing of  
30 packets in at least one of the mobile relay stations is based on information autonomously monitored by the mobile relay station about its neighbour stations only, this information being obtained by the mobile relay station

monitoring any packet that can be received at said mobile relay station, extracting said information from these monitored packets, for example identification information about the neighbour station that sent the particular packet, and locally storing the extracted information, for instance in a table with  
5 information about neighbour stations. Routing in a mobile relay station based on information autonomously gathered by the mobile relay station monitoring the traffic of the neighbouring stations, has the advantage that there is no need for exchanging routing information, respectively exchanging requests for routing information, between the mobile relay stations or between a mobile  
10 relay station and a central routing database. Thus, there is no additional burden on the network for establishing routing information in a mobile relay station, nor is there a need for a central database with routing information. As one skilled in the art will recognise, these improvements will result in a technically improved functioning of wireless networks, in particular an easier  
15 and cheaper routing of connections between mobile stations, for instance mobile phone stations.

Depending on the embodiment variant, each packet is routed in a mobile relay station either to one or to possibly more than one next station chosen from among the set of all of its neighbour stations, unless said mobile  
20 relay station is the sink station. The approach of both variants has the advantage that mobile stations can communicate without the involvement of any base stations. It is even possible that the approach results in a direct wireless connection between two mobile stations without involvement of an intermediate relay station. The variant in which more than one neighbour may  
25 be selected as a next relay station has the additional advantage that each packet can be routed concurrently along different paths; thereby, the reliability and efficiency of the routing method can potentially be improved.

Preferably, each packet contains a header indicating the source station which emitted the packet, at least one sink station to which the packet is  
30 destined, and at least one neighbour station to which the packet will be transmitted in the next hop. By preference, the field containing the information about the neighbour station(s) of the next hop is replaced in each intermediate relay station.

In a variant, each mobile relay station checks for each packet received if it has already relayed that packet, and in that case it checks if the packet received coincides with the packet previously relayed and otherwise requests a correction, which, for instance, consists in the respective mobile relay station re-transmitting the packet to at least one alternative neighbour station. This variant has the advantage that it makes it possible to correct transmission errors in packets without having to implement an explicit feedback channel for that purpose.

Two different variants are proposed to handle the situation where a mobile relay station is not able to further relay a received packet. In the first respective variant, the said mobile relay station sets a flag in the packet header and sends the packet to all or some of its known neighbours, which neighbours receiving such a said packet check if they can relay that packet to an alternative neighbour station. In the second respective variant, each mobile relay station checks for each packet which it transmitted whether that packet is relayed by at least one of its neighbour stations, and if this is not the case it re-transmits that packet to at least one alternative neighbour station. Both of these variants have the advantage that they help prevent packets from getting lost in a "dead end", even if this means that packets may have to be routed "backwards" in order to find an alternative path to the sink.

In a variant, the choice of the next station made in the mobile relay stations depends on the position of said next station, which position is determined, for instance, by a positioning system, for example GPS or a TPS, in at least some of said mobile stations and which position is communicated to the neighbour stations. For instance, the position may be a part of the above-mentioned identification information and may thus be gathered by neighbouring mobile relay stations monitoring the local traffic, as was explained above. Specifically, the decision may be based on the distance between the next station and the sink station and/or on the distance between the next station and the mobile relay station. This approach has the advantage that there is no need to flood the network with packets in random directions or to undertake complex enquiries about the topology of the network. Alternatively or in addition, the decision may also be based on the propagation conditions, traffic conditions,

and/or available bandwidth between the mobile relay station and the next station, and/or on the cost and/or the measured or expected delay for transmitting a packet to said next station. The position may also be used to identify and/or address each mobile station in the network.

5           According to the invention the objects mentioned above are particularly also achieved in that at least some of the mobile stations, for example mobile radio phones, which comprise sending and receiving means for directly sending and receiving packets to and from a neighbour mobile station through a wireless connection and which can be used in the wireless  
10 communication network as mobile relay stations, comprise processing means for autonomously monitoring information about at least some of its neighbour stations by extracting information from any packet that can be received at the mobile relay station and by storing the extracted information in a local memory of the mobile relay station, for instance arranged in a table with information  
15 about the neighbour stations, and for making routing decisions for packets sent to the mobile relay station based on said stored information.

The present invention will be explained in more detail, by way of example, with reference to the drawings in which:

Figure 1 is a conceptual representation of a wireless network  
20 showing a source, a sink, neighbours and mobile relay stations.

Figure 2 shows an example of the structure of a packet to be transmitted in a wireless network.

Figure 3 is a flow chart illustrating the steps executed for carrying out the method of the present invention.

25           Figure 4 is an alternative flow chart illustrating the steps executed for carrying out the method of the present invention.

In Figure 1, the reference numeral 3 refers to a wireless telecommunication network, for example a mobile radio network, e.g. a local

area or wide area wireless network, which comprises a plurality of nodes 4, 5, 6, N,  $N_{i-1}$ ,  $N_i$ ,  $N_{i+1}$ , indicated by black dots, each representing a mobile station, for example a mobile radio phone. In this wireless network 3, a packet 2, as illustrated in Figure 2, is guided by means of the method according to the present invention from its origin 5, i.e. its source 5, to its destination 6, i.e. its sink 6, along the path 7 indicated by the dashed line. For a packet 2 to get to its destination 6, it may require making numerous hops at intermediate nodes  $N_{i-1}$ ,  $N_i$ ,  $N_{i+1}$ , so-called relay nodes or relay stations, whereby an intermediate node  $N_i$  receives a packet 2 from a previous node  $N_{i-1}$  and passes it on, i.e. relays it, to the subsequent node  $N_{i+1}$ .

As is illustrated in Figure 2, a possible structure of a data packet 2 comprises a header field 22 and a data field 21, which data field 21 may contain user data, e.g. textual, numeric, or speech information, and further protocol information used by protocol layers which are not subject of this invention. A possible structure of the packet header 22 comprises a field 220 containing address and/or identification information about one or more sinks 6, i.e. destinations 6, of the data packet 2, a field 221 containing address and/or identification information about one or more neighbours N,  $N_{i-1}$ ,  $N_{i+1}$ , defined later in more detail, to whom the data packet is or was intended to be sent to in the next or previous hop, respectively, a field 222 containing address and/or identification information about the source 5 (or  $N_i$ ), i.e. the origin 5 (or  $N_i$ ) of the data packet 2, and a flag 223 which will be discussed later. It must be emphasised that the order of fields as illustrated in Figure 2 is only given as an example and that these fields could be arranged by one skilled in the art in any other order. Furthermore, one skilled in the art may decide to add further fields to header 22.

In wired networks, the transmission of information from one node to another is facilitated by wires interconnecting these nodes, whereby routing algorithms typically consult routing tables to find a path through the network. Hence, these routing algorithms track the topology of a wired network and maintain respective routing tables which form the basis for choosing appropriate paths through the network. Obviously, there are other criteria, such as a balanced load on different routes of the wired network, which must be



considered by these routing algorithms, but they are not a subject of this invention. In wireless networks, however, signals are typically emitted in all directions and, as opposed to wired networks, there are no physical paths between individual nodes, i.e. stations. Thus, in wireless networks with mobile  
5 stations it is not possible to establish the permanent topology of the network nor to store a permanent routing table.

If we define neighbours  $N$ ,  $N_{i-1}$ ,  $N_{i+1}$  of a particular node  $N_i$  to be nodes, i.e. stations,  $N$ ,  $N_{i-1}$ ,  $N_{i+1}$  which are able to receive signals from said particular node  $N_i$ , we may interpret the possibility of communicating with  
10 neighbours  $N$ ,  $N_{i-1}$ ,  $N_{i+1}$  as setting up or establishing virtual links to these neighbouring nodes, i.e. stations,  $N$ ,  $N_{i-1}$ ,  $N_{i+1}$  in the "neighbourhood" of said particular node  $N_i$ . Thus, the question for an intermediate node  $N_i$  of how to route a packet 2 through a wireless network 3 becomes the question of which neighbour  $N$ ,  $N_{i-1}$ ,  $N_{i+1}$  a packet 2 should be passed on to. For that purpose,  
15 each node, i.e. station,  $N_i$  in the wireless network 3 tracks all his neighbours  $N$ ,  $N_{i-1}$ ,  $N_{i+1}$  in step 100 illustrated in Figure 3, by "listening" for their packets 2, i.e. by monitoring any packet 2 that can be received at that particular node, and maintains a local table with information about these neighbours  $N$ ,  $N_{i-1}$ ,  $N_{i+1}$ . The tracking station  $N_i$  can identify its neighbours  $N$ ,  $N_{i-1}$ ,  $N_{i+1}$  based on  
20 identification information contained in the data packet 2 and updated at each hop with the sender's identification. Depending on the embodiment variant this identification information may be obtained by decoding the header 22 where the information may be contained in the source field 222 if this field is updated at each hop, it may be contained in an additional field not illustrated because  
25 the source field 222 is not changed but used to indicate the initial origin of the packet 2, or the identification information may be part of the data field 21 where it may be inserted by other protocol layers not subject of this invention. In the case where nodes are represented by a mobile radio phone, for example, the information obtained can be stored, for example, in its local memory or in a  
30 chipcard removably connected to a said mobile radio phone.

Although the wireless network 3 is not physically wired, through monitoring the neighbourhood, as described above, a network 3 with virtual links, or connections, is created, which may be thought of as being wired.

Essentially, all routing methods for wired networks known to one skilled in the art and not based on a centrally stored representation of a (permanent) topology of the network, for instance methods based on routing and flow control, could now be applied to this virtually wired network 3. One must keep  
5 in mind, however, that, as described above, a specific node  $N_i$  knows only its neighbours  $N$ ,  $N_{i-1}$ ,  $N_{i+1}$  but not the entire topology of the network 3. In other words, the present invention does not require individual nodes, i.e. stations, 4, 5, 6,  $N$ ,  $N_{i-1}$ ,  $N_i$ ,  $N_{i+1}$  to gather and store routing information in routing tables nor do these nodes 4, 5, 6,  $N$ ,  $N_{i-1}$ ,  $N_i$ ,  $N_{i+1}$  directly exchange routing information per  
10 se among each other. Routing decisions are based solely on information gleaned by nodes 4, 5, 6,  $N$ ,  $N_{i-1}$ ,  $N_i$ ,  $N_{i+1}$  themselves. Thus, the routing method proposed may be based on an isolated adaptive algorithm, wherein routing decisions made in a particular station  $N_i$  are based on information gathered by that station  $N_i$  by monitoring the network traffic in its "neighbourhood", e.g. by  
15 tracking received packets 2, as was described above. In this way, routing decisions, i. e. the choice of which neighbouring node(s)  $N$ ,  $N_{i-1}$ ,  $N_{i+1}$  packets are relayed to and thus the choice of how information is routed through the network 3, may be based on measurements or estimates of parameters such as current traffic, (local) topology, propagation conditions, distances (shortest  
20 path), delay times/requirements (fastest path), communication costs, bandwidth, or available power at the sender.

As was mentioned above, the presence of neighbouring stations, i.e. nodes  $N$ ,  $N_{i-1}$ ,  $N_{i+1}$ , is tracked in step 100 illustrated in Figure 3. The current traffic may be monitored, for instance, by tracking the number of packets 2  
25 emitted by individual neighbours  $N$ ,  $N_{i-1}$ ,  $N_{i+1}$  and by maintaining an up-to-date traffic indicator for each neighbouring station  $N$ ,  $N_{i-1}$ ,  $N_{i+1}$ , e.g. the number of packets 2 emitted by a particular station  $N$ ,  $N_{i-1}$ ,  $N_{i+1}$  during a pre-defined time period and divided by this time period. As nodes 4, 5, 6,  $N$ ,  $N_{i-1}$ ,  $N_i$ ,  $N_{i+1}$  may be identified and addressed by their (approximate) position, e.g. determined by the  
30 Global Positioning System (GPS) or by a terrestrial positioning system (TPS), the distance from a particular station  $N_i$  to its neighbours  $N$ ,  $N_{i-1}$ ,  $N_{i+1}$  and/or the distance from a neighbouring node  $N$ ,  $N_{i-1}$ ,  $N_{i+1}$  to the sink 6 may be easily determined by that particular station  $N_i$  by calculating the distance based on its own position, the position of the sink 6 indicated by the sink field 220 of the

packet to be routed, and the position of the neighbour  $N_i$ ,  $N_{i-1}$ ,  $N_{i+1}$  contained in the packet 2 received last from the respective neighbouring node  $N_i$ ,  $N_{i-1}$ ,  $N_{i+1}$ , which latter position is indicated through means described above in the context of step 100. It may be possible also for stations to include additional  
5 information in the data packets 2, for example information about their sending power or and/or information relating to the cost of communication, which may be used for routing purposes. A mobile station may also track the expected communication costs for sending a packet to each of its neighbour stations, for instance, by using information relating to the cost of communication received  
10 from a neighbour station and/or by considering respective distance information.

The routing method may be implemented by means of a software program, as illustrated by way of example in Figure 3, which is stored in the local memory of a station, for instance a mobile radio phone, or in a chipcard which is removably connected to the mobile radio phone, for example. After a  
15 station, i.e. a node,  $N_i$  receives a packet 2 in step 110 of the program, it tracks neighbour information relating to the sender  $N_{i-1}$  of the received packet 2 in step 100, as described above. Subsequently, in step 118 (step 112 will be described later), the program decodes the header information 22 and determines whether the receiving station  $N_i$  is listed in the neighbour field 221  
20 of the received packet 2, i.e. whether packet 2 was addressed to the receiving station  $N_i$ . If this is not the case, processing of the received packet 2 ends in step 120 of the program. Otherwise, in step 122, the program decodes the header 22 information and determines whether the receiving station  $N_i$  is listed as a sink 6 in field 220. If the receiving station  $N_i$  is indeed a sink 6, the packet  
25 2 is passed on internally in step 124 for further processing, for instance by protocol layers of the station's communication software, which is not a subject of this invention, and processing of the received packet 2 by this program ends in step 126.

Figure 4 shows an alternative flow chart where step 118 from the  
30 flow chart illustrated in Figure 3 is omitted. Consequently, the program according to the flow chart illustrated in Figure 4 determines in step 122 whether the receiving station  $N_i$  is listed as a sink 6 in field 220 prior to determining in step 128 whether or not it has to relay the packet 2, i.e. whether

it is listed as a neighbour in field 221. This alternative approach has the advantage that a sink station which receives a packet 2 without being addressed as a neighbour does not discard the packet 2. In Figure 4, step 100, in which the presence of neighbouring stations, i.e. nodes  $N$ ,  $N_{i-1}$ ,  $N_{i+1}$ , is tracked is shown after step 110 to illustrate that tracking may occur immediately following the receipt of a packet in step 110.

In the case where the receiving station  $N_i$  is not a sink 6, the program determines in step 128 of Figure 3 whether or not it has to relay the packet 2. If the receiving station  $N_i$  does not have to relay the packet 2, processing of the packet 2 by the program executing the routing method ends in step 130. In the case where the station  $N_i$  is addressed as a relay station  $N_i$ , the routing decision, i.e. the choice of the neighbour  $N$ ,  $N_{i-1}$ ,  $N_{i+1}$  to which the packet 2 will be sent to, is performed in step 104 of the program. The next neighbour  $N_{i+1}$ , which may also be referred to as the next hop, may be the sink 6 or it may be just another intermediate relay station  $N_{i+1}$  on the path 7 to the sink 6. The routing decision is based on criteria as described above. In a first variant of step 104, the routing decision is made anew for every packet 2 received (packet switching). In a second variant of step 104, all data packets 2 from a given source 5 and/or to a given destination 6 are routed along the same path(s) 7 (message switching, funneling). Thus in this second variant of step 104, at a particular hop, the packets 2 are always sent to the same next neighbour(s)  $N_{i+1}$ . In the second approach, packets may be forced along the same path(s), for example, during the duration of an end-to-end connection between a source station 5 and a sink station 6, or during the transmission of a message which comprises multiple packets 2, or simply by funneling all traffic to a particular destination 6 through the same relays. The first variant of step 104 may be more suitable for balancing the traffic load, as incoming packets 2 are distributed by the relay stations  $N_i$  among neighbouring stations  $N$ ,  $N_{i+1}$ , i.e. they follow different logical paths 7, and it may also adapt more flexibly to the changing positions of mobile relay stations  $N$ ,  $N_{i+1}$ , as the decision gets made anew for each packet 2 received.

In step 106, the header information 22 is updated by the program. Step 106 replaces the contents of the neighbour field 221 with the

identification, e.g. an address in the form of a position as described above or another unique identifier, respectively a list of identifications, of the next neighbour(s)  $N_{i+1}$  which resulted from the routing decision in step 104.

- Furthermore, step 106 may replace the contents of the source field 222 or, if  
5 the source field 222 is kept unchanged in order to indicate always the initial origin of the packet 2, update another additional header field not illustrated with the relay station's  $N_i$  own identification.

- As was mentioned above, in the context of step 106 of the program, multiple addresses (positions) of neighbouring nodes, i.e. stations,  $N$ ,  $N_{i+1}$  may  
10 be inserted in the neighbour field 221 of the packet header 22. A packet 2 may thereby be routed concurrently along various paths, which corresponds to multi-path routing in wired networks and is also referred to as bifurcated routing. This approach may improve the routing reliability, as the chances of at least one of these packets reaching the sink 6 are increased. On the other  
15 hand, however, this improved reliability comes at the price of possibly decreasing communication efficiency, as a heavier load is put on the wireless network 3.

- In an alternative approach, a relay station  $N_i$  could simply broadcast a packet 2 to all its neighbours  $N$ ,  $N_{i-1}$ ,  $N_{i+1}$  (flooding), without indicating  
20 individual identifications (address/position) of these neighbours  $N$ ,  $N_{i-1}$ ,  $N_{i+1}$  in the packet header 22. However, this approach may be very inefficient as the network 3 may be unnecessarily flooded with packets 2. This approach may be used in a local wireless network with a limited number of stations.

- Multi-destination routing can be achieved as in any other network,  
25 namely by inserting a list of destinations/sinks 6 in the sink field 220 of header 22. Special address values, i.e. multicast or group addresses, may be used to identify a specific group or subset of stations; a special broadcast address may be used to identify all stations. The same approach may also be used to address neighbours in field 221. In the latter case a multicast address may  
30 identify a subset of the neighbouring nodes, for example all neighbours of a certain make or sending power, whereas a broadcast address in field 221 may

target all neighbours that can be reached from the sender (source or relay station).

In step 108 of the program, the relay station  $N_i$  sends out the packet 2 with the header 22 adapted in the previous step 106.

5           Due to the fact that in wireless networks 3 signals are typically emitted in all directions, i.e. the transmission occurs omnidirectionally, the sender  $N_i$  who sent a packet 2 to a relay station  $N_{i+1}$  is generally able to receive that packet 2 when it is sent out by said relay station  $N_{i+1}$  and thus may inspect the transmission of a relay station  $N_{i+1}$ . As is illustrated in Figure 3, optional  
10   step 112 of the program, executing the routing method on a first station  $N_i$ , checks if a received packet 2 was sent out by a second station  $N_{i+1}$  which was previously addressed by the first station  $N_i$  as a relay station  $N_{i+1}$  (neighbour). If this is indeed the case, in step 114, the program determines whether the  
15   contents of said packet 2 received from said relay station  $N_{i+1}$  corresponds to the contents of the packet 2 originally sent by said first station  $N_i$  and whether said received packet 2 did not get corrupted. For that purpose, data packets 2 may be temporarily stored by a sending station  $N_i$  (step 108). If relay stations  
20    $N_{i+1}$  relay packets in a deterministic manner, for example immediately after their arrival at the relay station  $N_{i+1}$ , before sending out any other packets, this inspection/verification can be achieved without the necessity of other protocol  
data elements. Otherwise, this type of inspection/verification must include additional means to correctly identify a data packet 2, for example an additional  
packet number or additional protocol data elements inserted in the data field 21  
25   by other protocol layers of the station's communication software, such as packet or frame sequence numbers. If the data contents of said sent and received packets 2 do not coincide, a correction is initiated in step 116 and the original packet 2 is resent by said first station in step 108, for instance. Thus, such an inspection/verification approach makes it possible to implement error-correction without implementation of an explicit feedback channel.

30           In cases where a station  $N_{i+1}$  is not able to transmit a packet 2 any further, for example because it does not have any information about neighbouring nodes which would be suitable relay stations for routing the said

packet 2 along a path to the sink 6, said station  $N_{i+1}$  may set flag 223 (indicating "please help me") in the packet header 22 and send the packet 2 to its neighbours  $N_i$ ,  $N_i$ , either by using a broadcast or multicast address, as described above, or by listing specific neighbours  $N_i$ ,  $N_i$  in field 221 of the header 22. Upon receiving such a packet, each neighbour  $N_i$ ,  $N_i$  addressed in the header tries to find an alternative route/neighbour. However, flag 23 is not mandatory. Instead of using flag 23, the sender  $N_i$  who sent a packet 2 to a relay station  $N_{i+1}$  may simply wait for a pre-defined period of time for the relay station  $N_{i+1}$  to relay the packet 2. If the expected relaying of said packet 2 does not take place within the pre-defined period of time, the said sender  $N_i$  may try to find an alternative route/neighbour  $N_i$ ,  $N_{i+1}$ , thus, there is no need for flag 23. The latter approach may be more advantageous because in the first approach the packet 2 with flag 23 set may possibly get lost, for instance because the two stations  $N_i$ ,  $N_{i+1}$  are moving apart so that the packet 2 from the relay station  $N_{i+1}$  cannot reach the sender  $N_i$ .

It should be clarified that preferably each mobile station 4, 5, 6,  $N_i$ ,  $N_{i+1}$ ,  $N_i$ ,  $N_{i+1}$  in the wireless communication network 3 may function as a relay station. Even a source station 5 executes parts of the software program illustrated in Figure 3. In step 101 of the program, the source station 5 prepares the packet header 22 by setting its own identification (address/position) in the source field 222 and by setting the identification (address/position) of the destination in the sink field 220. In step 104, the program handles the routing decision as described above, i.e. depending on the destination, it determines the neighbour to which the packet 2 will be sent next. The next neighbour, which may also be referred to as the next hop, may be the destination, i.e. the sink 6, or it may be just a first intermediate relay station on the path 7 to the sink 6. The routing decision is based on criteria as described above.

By means of a software or hardware switch, activated, for instance, by a dedicated function key of the mobile station, it may also be possible to switch a mobile station, for example a mobile radio phone, e.g. a mobile radio phone in a GSM- or UMTS-network or a mobile radio phone in a mobile network according to other standards such as PCN, NMT, TACS, PDC, or DCS1800, to the regular mode, whereby any functionality of the routing method

described will be bypassed so that packets will be submitted according to the conventional way, via base stations, and that the mobile station no longer functions as a potential relay station. This fact could also be reflected easily by means of a special flag in the packet or by using different formats of packets for conventional mode or routing mode so that a mobile station in regular mode is not being tracked as a potential relay station by stations operating in routing mode.

It should be pointed out that the actual end-to-end transport control as well as any error detection and correction is handled by protocol layers of the communication software which is not a subject of this invention. Such protocol layers, known to one skilled in the art, handle communication issues such as the proper sequencing of packets, the correction of lost or duplicated packets, for example by using frame or packet sequence numbers, or the detection and correction of corrupted packets, for example by means of cyclic redundancy checks (CRC). It should also be pointed out that the proposed routing method can be used for connection-oriented and/or connection-less types of communication protocols as well as for bidirectional and/or unidirectional communication modes.

The proposed method allows the routing of packets 2 from a source 5 to a destination 6 without centrally storing the exact topology of the network 3. For a station 4, 5, 6, N,  $N_{i-1}$ ,  $N_i$ ,  $N_{i+1}$  to be a relay station  $N_{i-1}$ ,  $N_i$ ,  $N_{i+1}$ , it is sufficient to store information about its set of neighbours; however, there is no need to update routing information at a node 4, 5, 6, N,  $N_{i-1}$ ,  $N_i$ ,  $N_{i+1}$ . In particular, there is no exchange of routing information between a central unit (controller) and a node 4, 5, 6, N,  $N_{i-1}$ ,  $N_i$ ,  $N_{i+1}$ . It should be mentioned that the way of identifying and addressing source 5, relay  $N_{i-1}$ ,  $N_i$ ,  $N_{i+1}$  (, 4, N), and sink 6 stations, as it was described above, is not limited to using position information, but could also be done using unique identifiers which do not include position information. In this latter case, the proposed routing method would make use of additional routing algorithms known to one skilled in the art to find suitable routes from a source 5 to a sink 6 in the wireless telecommunication network 3.



Furthermore, it must be pointed out that not necessarily all stations are mobile stations. In some cases it may be advantageous to have some fixed relay stations (not base stations) which have the means necessary to act as a relay station as described above, possibly with a transmission power exceeding  
5 that of conventional mobile stations.

Additionally, fixed stations connected to a fixed network, for example the public switched telephone network (PSTN), a dedicated backbone, or the Internet, and provided with means to send and receive data to and from a said fixed network as well as means to send and receive packets 2 to and from a  
10 wireless telecommunication network 3 operating according to the proposed routing method may function as gateways between a said fixed network and a said wireless network 3. Thus, by means of such gateways, communication in a said wireless network 3 may be extended to a said fixed network and vice versa. Moreover, such gateways may also be used to interconnect  
15 geographically separated said wireless networks 3 via fixed networks.

The routing method described may be implemented, for example, in densely populated areas, for instance metropolitan areas, or in locations with a high concentration of people, for instance on the sites of private companies, government agencies, or university campuses. As mentioned before, the  
20 processing and storage means may be implemented in the local memory of mobile radio telephones, for instance, or in chipcards, for example SIM-cards, which may be removably connected to a mobile radio phone. Thus, mobile radio phones or chipcards may be sold to interested customers. Alternatively, at an appropriate fee, the respective software program may be loaded into the  
25 memory of the mobile radio phone or of the chipcard.

## Claims

1. Method for routing packets (2) within a wireless telecommunication network (3), said packets (2) being transmitted from one source station (5) in said network to at least one sink station (6) through one or a plurality of relay stations ( $N_{i-1}$ ,  $N_i$ ,  $N_{i+1}$ ), at least one of said relay stations ( $N_{i-1}$ ,  $N_i$ ,  $N_{i+1}$ ) being a mobile relay station, at least two of said stations (4, 5, 6,  $N$ ,  $N_{i-1}$ ,  $N_i$ ,  $N_{i+1}$ ) being neighbour stations, wherein packets (2) can be directly transmitted (108-110) through a wireless connection (7) between each pair of neighbour stations, characterised
- 10 in that the routing of packets (2) in at least one of said mobile relay stations ( $N_i$ ) is based on information autonomously monitored by said mobile relay station ( $N_i$ ) about at least some of its neighbour stations ( $N$ ,  $N_{i-1}$ ,  $N_{i+1}$ ), said information being obtained by said mobile relay station ( $N_i$ ) monitoring any packet (2) that can be received at said mobile relay station ( $N_i$ ), extracting said
- 15 information from said monitored packets (2), and locally storing said extracted information.
2. Method according to the preceding claim, characterised in that said extracted information comprises at least identification information about the neighbour station ( $N$ ,  $N_{i-1}$ ,  $N_{i+1}$ ) that sent the packet (2) from which the
- 20 information was extracted.
3. Method according to one of the preceding claims, characterised in that each packet (2) sent to a said mobile relay station ( $N_i$ ) is routed in said mobile relay station ( $N_i$ ) to one next mobile relay station ( $N_{i+1}$ ) chosen from among the set of all of its neighbour stations ( $N$ ,  $N_{i-1}$ ,  $N_{i+1}$ ), unless said mobile
- 25 relay station ( $N_i$ ) is a sink station (6).
4. Method according to one of the claims 1 to 2, characterised in that each packet (2) sent to a said mobile relay station ( $N_i$ ) can be routed in said mobile relay station ( $N_i$ ) to more than one neighbour mobile relay station ( $N$ ,  $N_{i+1}$ ) chosen from among the set of all of its neighbour stations ( $N$ ,  $N_{i-1}$ ,  $N_{i+1}$ ).

5. Method according to one of the preceding claims, characterised in that each packet (2) contains a header (22) indicating the source station (5) which emitted the packet (2) and at least one sink station (6) to which the packet is destined.

5           6. Method according to the preceding claim, characterised in that said header (22) contains at least one field (221) indicating at least one neighbour mobile relay station ( $N_{i+1}$ ) to which said packet (2) will be transmitted in the next hop.

10           7. Method according to the preceding claim, characterised in that said field (221) is replaced in each of said intermediate mobile relay stations ( $N_{i-1}$ ,  $N_i$ ,  $N_{i+1}$ ).

15           8. Method according to one of the preceding claims, characterised in that each mobile relay station ( $N_{i-1}$ ,  $N_i$ ,  $N_{i+1}$ ) checks (112) for each packet (2) received if it has already relayed that packet, and in that case checks (114) if the packet (2) received coincides with the packet previously relayed and otherwise re-transmits (116) the packet (2).

20           9. Method according to one of the preceding claims, characterised in that a mobile relay station ( $N_{i+1}$ ) which is not able to relay a received packet (2) sets a flag (223) in the packet header (22), and a neighbour mobile relay station ( $N_i$ ), addressed in that packet header (22) and receiving such a said packet (2), checks if it can relay that packet (2) to an alternative neighbour mobile relay station ( $N$ ,  $N_{i+1}$ ).

25           10. Method according to one of the preceding claims, characterised in that each mobile relay station ( $N_i$ ) checks for each packet (2) which it transmitted if that packet (2) is relayed by at least one of its neighbour mobile relay stations ( $N_{i+1}$ ), and if this is not the case re-transmits that packet (2) to at least one alternative neighbour mobile relay station ( $N$ ,  $N_{i+1}$ ).

11. Method according to one of the claims 3 to 10, characterised in that the choice of the next mobile relay station ( $N_{i+1}$ ) made (104) in the mobile

relay stations ( $N_i$ ) depends on the position of said next mobile relay station ( $N_{i+1}$ ).

12. Method according to the preceding claim, characterised in that said position is determined by a positioning system in at least some of said  
5 mobile relay stations (4, 5, 6,  $N$ ,  $N_{i-1}$ ,  $N_i$ ,  $N_{i+1}$ ), and is communicated to the neighbour mobile relay stations.

13. Method according to one of the claims 11 or 12, characterised in that the choice (104) of the next mobile relay station ( $N_{i+1}$ ) made in the mobile relay stations ( $N_i$ ) depends on the distance between said next mobile relay  
10 station ( $N_{i+1}$ ) and said sink station (6).

14. Method according to one of the claims 11 to 13, characterised in that the choice (104) of the next mobile relay station ( $N_{i+1}$ ) made in the mobile relay stations ( $N_i$ ) depends on the distance between said next mobile relay station ( $N_{i+1}$ ) and a said mobile relay station ( $N_i$ ).

15 15. Method according to one of the claims 3 to 14, characterised in that the choice (104) of the next mobile relay station ( $N_{i+1}$ ) made in the mobile relay stations ( $N_i$ ) depends on the propagation conditions between a said mobile relay ( $N_i$ ) station and said next mobile relay station ( $N_{i+1}$ ).

16. Method according to one of the claims 3 to 15, characterised in  
20 that the choice (104) of the next mobile relay station ( $N_{i+1}$ ) made in the mobile relay stations ( $N_i$ ) depends on the traffic conditions between a said mobile relay station ( $N_i$ ) and said next mobile relay station ( $N_{i+1}$ ).

17. Method according to the preceding claim, characterised in that the choice (104) of the next mobile relay station ( $N_{i+1}$ ) made in the mobile relay  
25 stations ( $N_i$ ) depends on the available bandwidth between a said mobile relay station ( $N_i$ ) and said next mobile relay station ( $N_{i+1}$ ).

18. Method according to one of the claims 3 to 17, characterised in that the choice (104) of the next mobile relay station made ( $N_{i+1}$ ) in the mobile

relay stations ( $N_i$ ) depends on the costs for transmitting a packet to said next mobile relay station ( $N_{i+1}$ ).

19. Method according to one of the claims 3 to 18, characterised in that the choice (104) of next mobile relay station ( $N_{i+1}$ ) made in the mobile relay stations ( $N_i$ ) depends on the measured or expected delay for transmitting a packet to said next mobile relay station ( $N_{i+1}$ ).

20. Method according to one of the preceding claims, characterised in that each mobile relay station (4, 5, 6, N,  $N_{i-1}$ ,  $N_i$ ,  $N_{i+1}$ ) is identified in said network (3) by its position.

21. Method according to one of the preceding claims, characterised in that each mobile relay station (4, 5, 6, N,  $N_{i-1}$ ,  $N_i$ ,  $N_{i+1}$ ) is addressed in said network (3) by its position.

22. Method according to one of the preceding claims, characterised in that it is performed on a network of mobile phone stations (4, 5, 6, N,  $N_{i-1}$ ,  $N_i$ ,  $N_{i+1}$ ).

23. Mobile relay station (4, 5, 6, N,  $N_{i-1}$ ,  $N_i$ ,  $N_{i+1}$ ) which can be used in a wireless telecommunication network (3) in which packets are transmitted from one source station (5) to at least one sink station (6) through one or a plurality of relay stations ( $N_{i-1}$ ,  $N_i$ ,  $N_{i+1}$ ), whereby said mobile relay station can be used as a relay station ( $N_{i-1}$ ,  $N_i$ ,  $N_{i+1}$ ), said mobile relay station ( $N_i$ ) comprising a sender and a receiver for directly sending (108) and receiving (110) packets (2) to and from a neighbour station (N,  $N_{i-1}$ ,  $N_{i+1}$ ) through a wireless connection (7), characterised

in that said mobile relay station ( $N_i$ ) comprises a processor for autonomously monitoring information about at least some of its neighbour stations (N,  $N_{i-1}$ ,  $N_{i+1}$ ) by extracting information from any packet (2) that can be received at said mobile relay station ( $N_i$ ) and by storing said extracted information in a memory of said mobile relay station ( $N_i$ ), and for making routing

decisions (104) for packets (2) sent to said mobile relay station ( $N_i$ ) based on said stored information.

24. Mobile relay station according to the preceding claim,  
characterised in that said extracted information comprises at least identification  
5 information about the neighbour station ( $N$ ,  $N_{i-1}$ ,  $N_{i+1}$ ) that sent the packet (2)  
from which the information was extracted.

25. Mobile relay station according to one of the claims 23 or 24,  
characterised in that it further comprises a positioning system which can  
determine its position in said wireless telecommunication network (3).

10 26. Mobile relay station according to the preceding claim,  
characterised

in that the choice of the next mobile relay station ( $N_{i+1}$ ) to which the  
packets (2) sent to said mobile relay station ( $N_i$ ) are routed (104) depends on  
the said position of said next mobile relay station ( $N_{i+1}$ ).

15 27. Mobile relay station according to one of the claims 23 to 26,  
characterised in that it further comprises

a memory for temporarily storing sent packets (2),

comparison means for comparing (114) received packets (2) with  
said packets stored in said memory,

20 and re-transmission means for re-transmitting (116) a said received  
packet (2) when said mobile relay station determines that said received packet  
corresponds to stored packets and when the received packets are different  
from said stored packets.

28. Mobile relay station ( $N_i$ ) according to the preceding claim,  
25 characterised in that it further comprises

checking means for checking for each packet (2) which it transmitted whether that packet (2) is relayed by at least one of its neighbour mobile relay stations ( $N_{i+1}$ ), and

re-transmission means for re-transmitting said packet (2) to at least  
5 one alternative neighbour mobile relay station ( $N, N_{i+1}$ ) if said packet (2) was not relayed by at least one of its neighbour mobile relay stations ( $N_{i+1}$ ).

29. Mobile relay station ( $N_{i+1}$ ) according to one of the claims 23 to 28, characterised in that it further comprises

flag-setting means for setting a flag (223) in the packet header (22) if  
10 said mobile relay station ( $N_{i+1}$ ) is not able to relay a received packet (2), and

means for relaying a received packet (2) to an alternative neighbour mobile relay station ( $N, N_{i+1}$ ), if said mobile relay station ( $N_i$ ) is addressed in the packet header (22) of that received packet and if a said flag (223) is set in that received packet (2).

15 30. Mobile relay station according to one of the claims 23 to 29, characterised in that it further comprises cost determination means for determining the costs for sending a packet to each of said neighbour mobile relay stations.

20 31. Mobile relay station according to one of the claims 23 to 30, characterised in that it further comprises routing means for performing the routing method of one of the claims 1 to 22.

32. A program storage device readable by a programmable mobile station (4) which can be used as a mobile relay station in a wireless communication network (3), tangibly embodying a program of instructions  
25 executable by said programmable mobile relay station to perform the routing method of one of the claims 1 to 22.

33. Wireless communication network (3) comprising at least one mobile relay station (4) according to one of the claims 23 to 31.

34. Method for routing packets (2) within a wireless telecommunication network (3), wherein said packets (2) are transmitted from  
5 one source station (5) in said network to at least one sink station (6) through one or a plurality of relay stations ( $N_{i-1}$ ,  $N_i$ ,  $N_{i+1}$ ), at least one of said relay stations ( $N_{i-1}$ ,  $N_i$ ,  $N_{i+1}$ ) being a mobile station, at least two of said stations (4, 5, 6,  $N$ ,  $N_{i-1}$ ,  $N_i$ ,  $N_{i+1}$ ) being neighbour stations, whereby packets (2) can be directly transmitted (108-110) through a wireless connection (7) between each pair of  
10 neighbour stations, characterised

in that the routing of packets (2) in at least one of said mobile relay stations (4) is based on information monitored by said mobile relay station about at least some of its neighbours stations.



FIG. 1

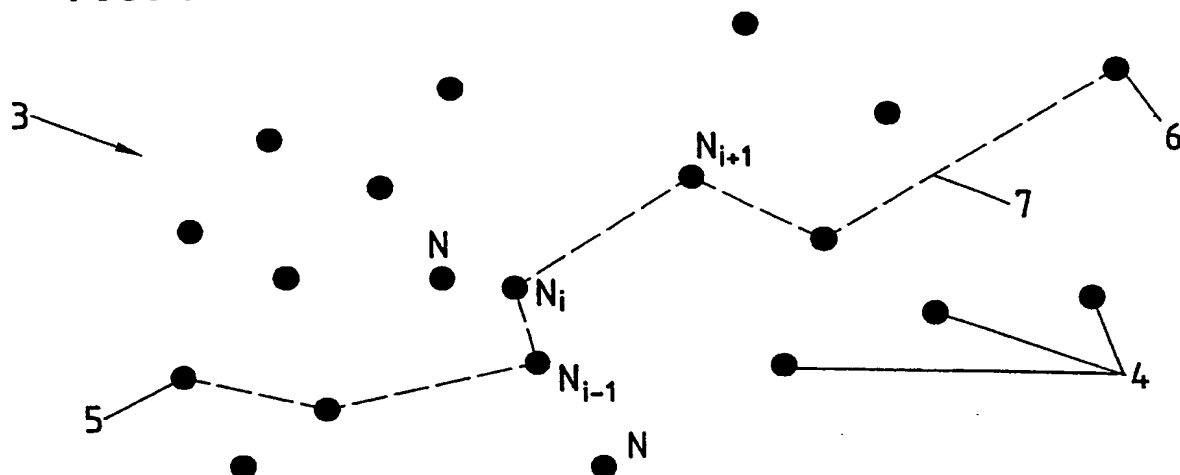
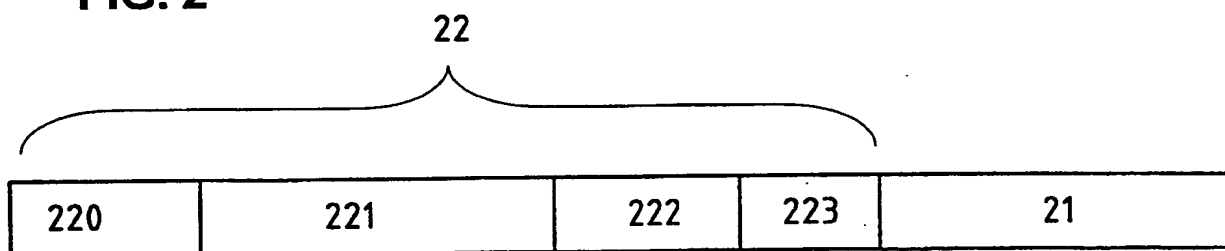


FIG. 2



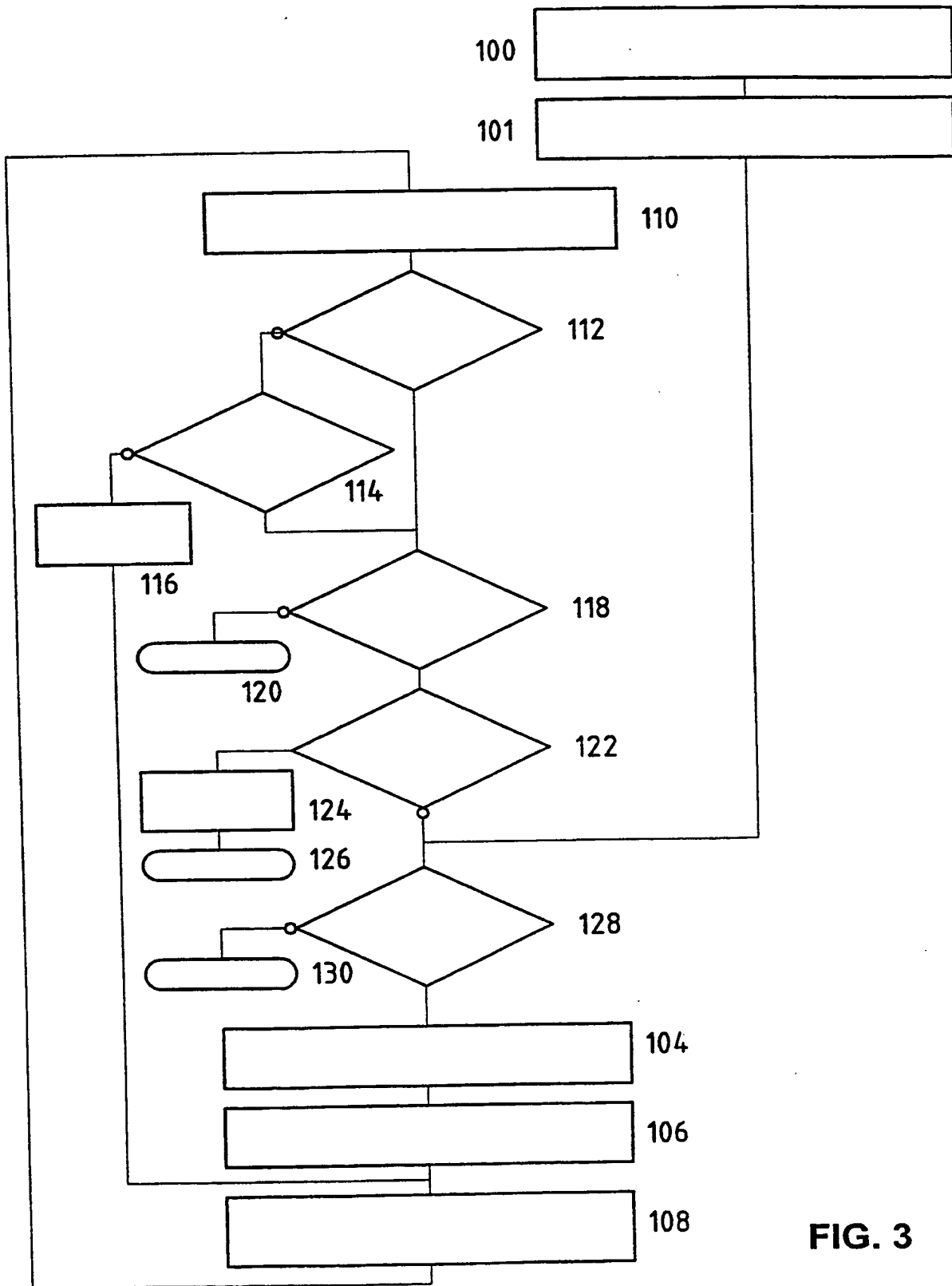


FIG. 3

3/3

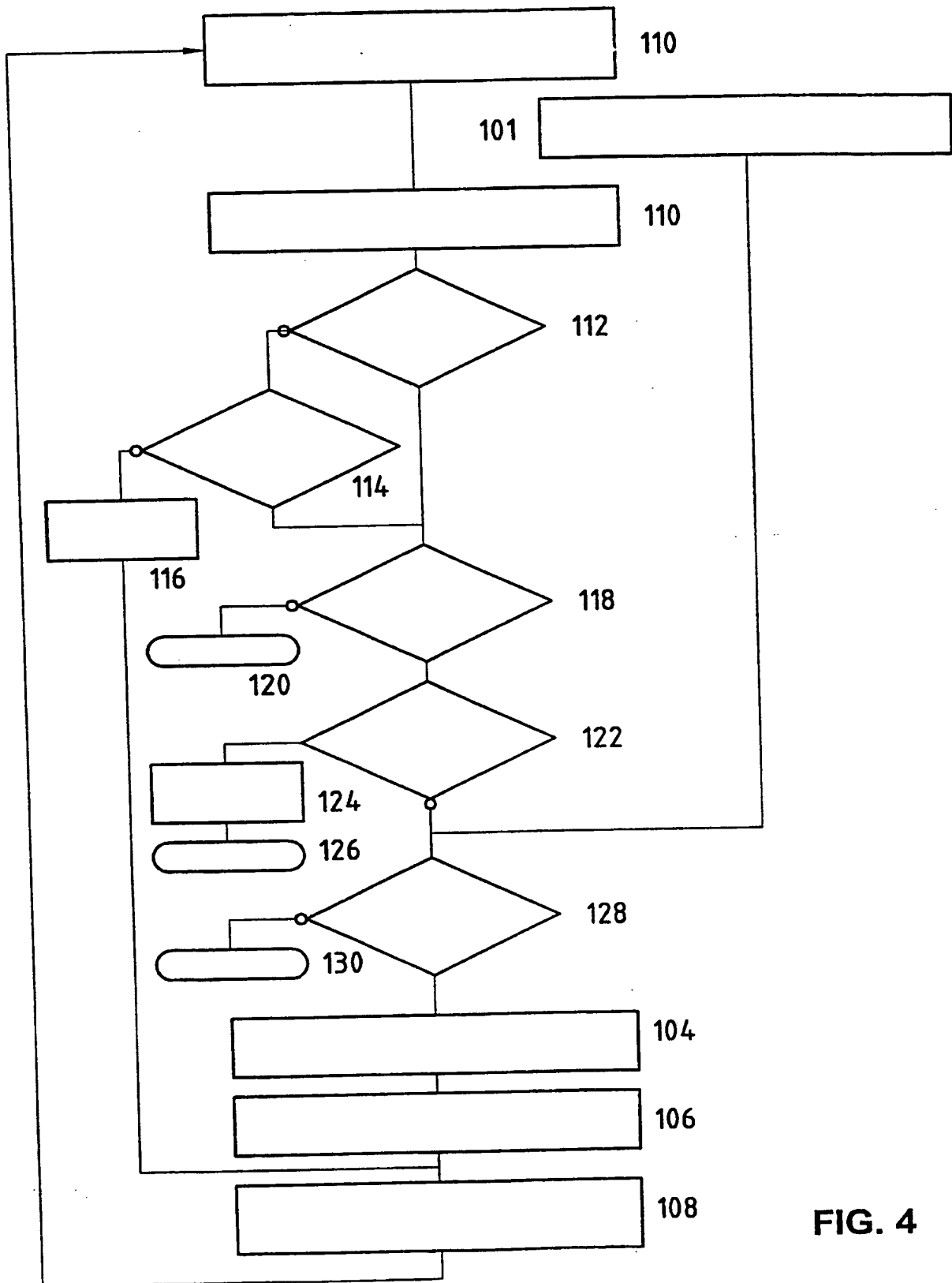


FIG. 4

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